Fatigue test program for NaX® Q110-E

Executive Summary

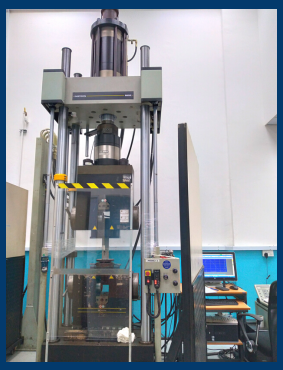
This test program examines the fatigue behaviour (i.e. fatigue resistance) of NaX® Q110-E, manufactured by NAUTEC, under sinusoidal uniaxial cyclic compressive loadings in force-controlled mode and the assessment of the results with regard to questions of fatigue design.

Product:
NaX® Q110-E

Market:
Wind Energy

Application:
Foundations of support structures for wind turbines

Technology



Fatigue test set up using an Instron UTM model 8805 of 1000 kN capacity

Cylindrical specimens (75 mm diameter x 225 mm height) for fatigue testing.

For more information contact:
Tel: Tel: +65 6298 2671
Email: contact@nautec.com
URL: www.nautec.com

A brand of MBCC Group

The Fatigue Test

The fatigue test was performed between a minimum stress level of 0.05 and four (4) maximum stress levels of 0.60, 0.65, 0.75 and 0.85. Based on this, in particular, applicability of the fatigue verification according to CEB-FIP Model Code 90 and fibModel Code 2010 were examined. The investigations also determined the input parameters necessary for fatigue design. In addition, information concerning fatigue deformation in compression was evaluated, with reference to Chinese National Standard GB/T 50082.

NaX® Q110-E UHPC

The test material NaX® Q110-E is an ultra-high performance cementitious grout (UHPC) with a maximum grain size of 1 mm that exceeds the current highest compressive strength class C100/115 in the Eurocode and meets the highest strength class designation of C120/140 in the latest fib Model Code 2010.

This exceptional grout product was designed to meet the stringent requirement for grouting of offshore wind turbine foundations, establishing the critical load transfer link between the turbine support structure and the foundation, validated with a DNV Type Approval Certificate.

Fatigue Performance

Currently, there is no consensus on whether increasing concrete (or grout) compressive strength beyond the scope of current standards (i.e.C100/115) such as in UHPC, will reduce the fatigue life in compression. Unlike concrete grades up to C100/115 that has been established in practice and governed in standards such as EN 206 and Eurocode 2, there is limited information on the fatigue performance of UHPC, especially for grouts with small aggregate grain size.

Furthermore, it is noted that no grouts were examined in the course of the preparation of the new rules in the fib-Model Code 2010. As such, this fatigue study aims to investigate the applicability of the respective Woehler curves and therefore the transferability of the new design approaches to the grout NaX® Q110-E from an experimental program.

Fatigue test program for NaX® Q110-E

Executive Summary

Compressive Stress Level

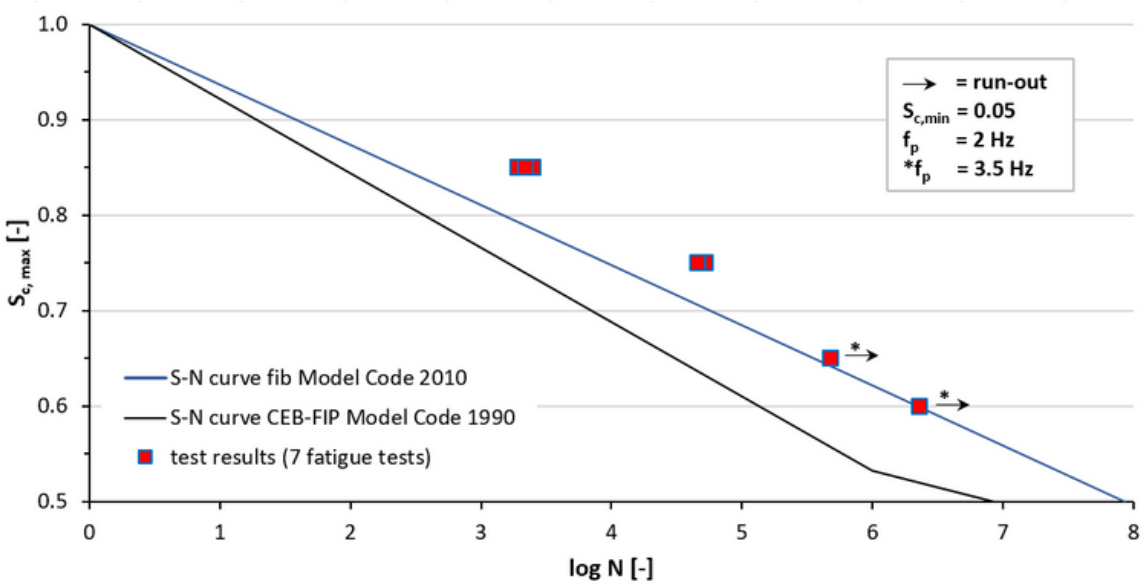


Figure 1: Test results for Nautec NaX® Q110-E grout material and Woehler curve in accordance with CEB-FIP Model Code 90 and fib-Model Code 2010 in relation to a minimum compressive stress level of Sc,min = 0.05

Fatigue Deformation

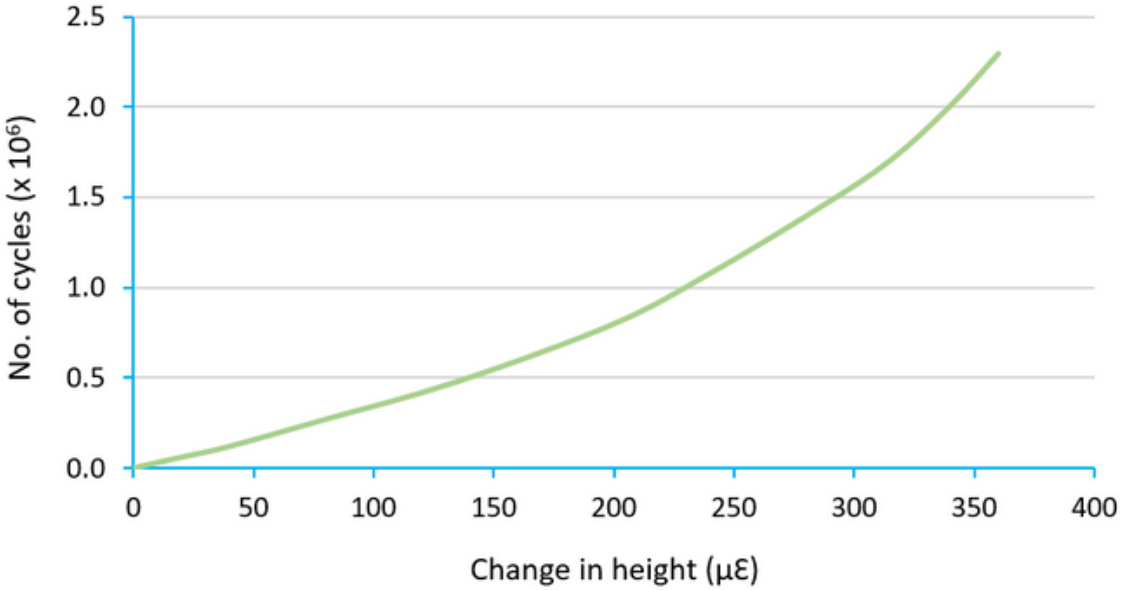
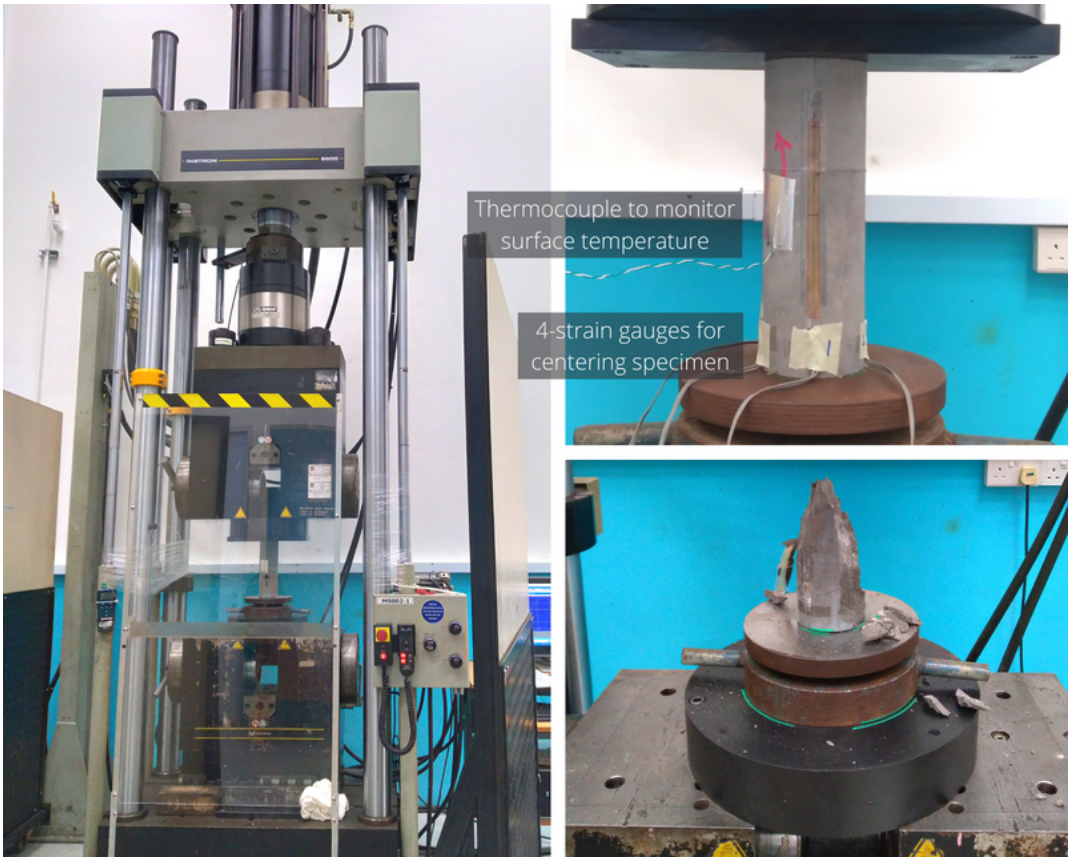


Figure 2: Combined test results for fatigue deformations of NaX® Q110 (Sc,min = 0.05; Sc,max = 0.60 to 0.65).

Fatigue test program for NaX® Q110-E

Executive Summary



Fatigue test set up using an Instron UTM model 8805 of 1000 kN capacity (left); close-up view of test specimen during fatigue test (upper right); fractured specimen from fatigue test (lower right).

Conclusion

The fatigue test results show that the number of cycles to failure of NaX® Q110-E significantly exceed the specifications of CEB-FIP Model Codes 90, and are also higher than the numbers of cycles to failure specified under fib-Model Code 2010, at all of the investigated stress levels (Fig.1). Based on these results, NaX® Q110-E is suitable for fatigue verification using the approaches according to the Woehler curves specified under CEB-FIP Model Code 90 and fib-Model Code 2010.

Post-fatigue test residual compressive strength and residual modulus of elasticity evaluated from a fatigue specimen tested at maximum stress level of 0.60 which did not reached failure after 2.3 million cycles ("run-out"), was 3.4% higher than the average initial compressive strength and 9.7% lower than the initial modulus of elasticity, respectively. Finally, fatigue deformation in compression evaluated with reference to Chinese National Standard GB/T 50082 recorded a strain of 360 με after 2.3 million cycles at a minimum stress level of 0.05 and maximum stress level of 0.60 (Fig. 2).

NaX® Q110-E is certified by DNV through a Type Approval Certification (TAC) program as a ready to use silo-based cementitious offshore wind grout. On mixing with controlled amount of potable water, it produces a flowable, cohesive and impermeable ultra-high performance cementitious (UHPC) grout, which develops high compressive strength in extreme short period of time under low temperature environment. At 28-day, the product has high compressive strength exceeding 125 MPa and E-modulus of more than 40 GPa.

NaX® Q110-E exhibit excellent flowability with high inherent cohesiveness and anti-washout property and can be easily pumped into structures with narrow constrictions, filling of annulus in pipe-in-pipe systems or hollow sections, typically found in offshore wind foundation system like monopiles, tripods and jacket structures. Early-age cycling (EAC) test shows no detrimental effect on compressive strength development, nor any instability such as segregation or sedimentation of components.

For more information contact:
Tel: +65 6298 2671
Email: contact@nautec.com
URL: www.nautec.com